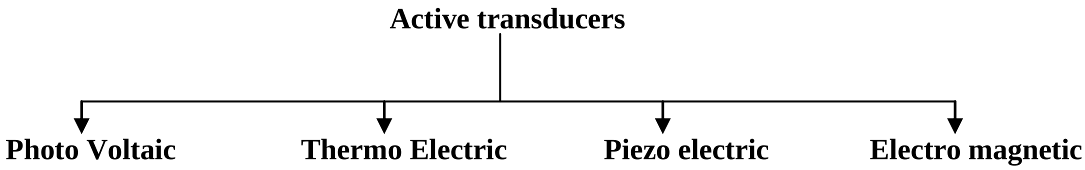
Module-4

TRANSDUCERS

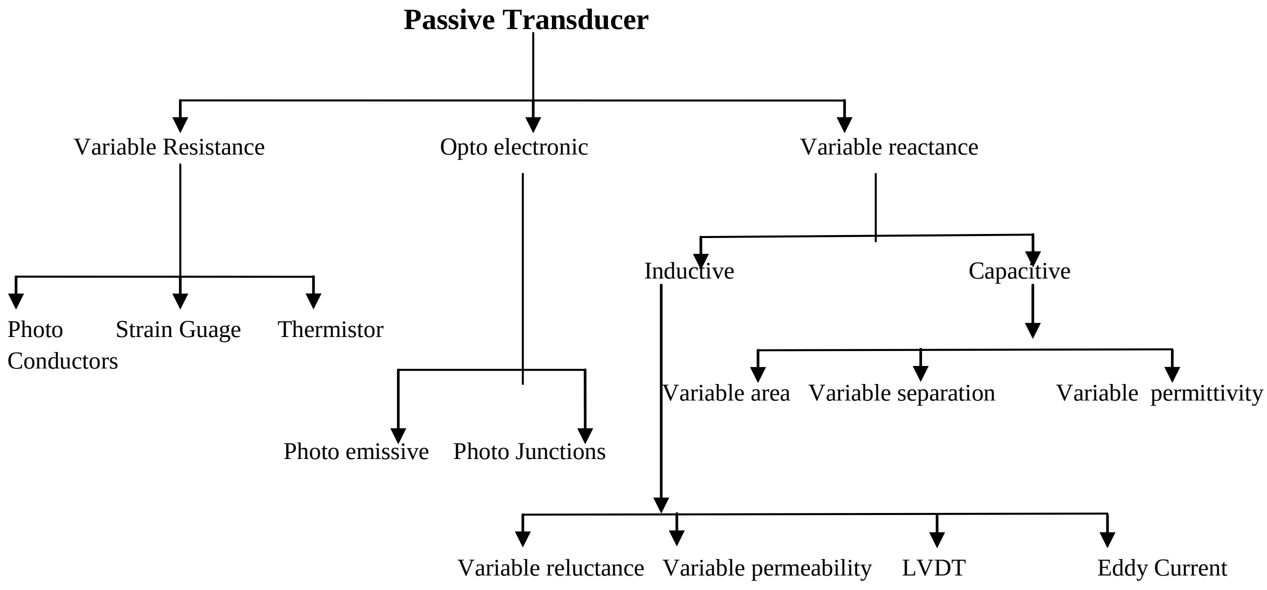
Syllabus: Introduction ,Passive Electrical transducers, Resistive Transducers, Resistance Thermometers, Thermistor, Linear Variable Differential Transformer(LVDT),Active Electrical Transducers, Piezoelectric Transducer, Photoelectric Transducer.

Introduction:

- **Transducer** is a device which converts a physical quality such as pressure, temperature, displacement, force etc., to equivalent electrical signal either in terms of voltage or current.
- **Transducers** are mainly classified as **Active Transducer and Passive Transducer.**
- **Active transducers** develop an electrical parameter (i.e. voltage /current) which is proportional to the quantity under measurement. These transducers are self generating type and they do not require any external source or power for their operation.



- **Passive Transducers** do not generate any electrical signal by themselves. they use an external source to obtain electrical signals and depend on change in electrical parameter(R,L,C).



Comparision:

Sr. No.	Active Transducers	Passive Transducers
1.	They do not require any external source or power for their operation.	They require an external source of power for their operation.
2.	They are self generating type transducers.	They are not self generating type transducers.
3.	They produce electrical parameter such as voltage or current proportional to the physical parameter under measurement.	They produce change in the electrical parameter such as inductance, resistance or capacitance in response to the physical parameter under measurement.
4.	Examples : Thermocouple, photocell, piezoelectric transducers.	Examples : Thermistor, RTD, LDR, LVDT, phototransistor.

- **Transducers are also classified as Primary and Secondary Transducers**

Sr. No.	Primary Transducer	Secondary Transducer
1.	A transducer which converts physical quantity into mechanical signal is called **primary transducer**.	A transducer which converts mechanical signal into an electrical signal is called **secondary transducer.**
2.	They do not require any electrical power for their operation.	They require electrical power for their operation.

Electrical Transducer

- A transducer which gives output in electrical form it is known as **electrical transducer**.
- Actually, electrical transducer consists of two parts which are very closely related to each other. These two parts are sensing or detecting element and transduction element. The sensing or detecting element is commonly known as **sensor**.
- Definition states that **sensor is a device that produces a measurable response to a change in a physical condition, such as temperature or thermal conductivity, or to a change in a chemical concentration.**
- The transduction element transforms the output of the sensor to an electrical output, as shown in the Fig.

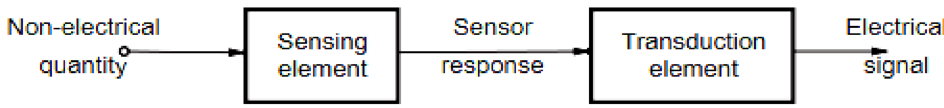


Fig. Electrical Transducer

Some Important Definitions

1. **Transducer** : A transducer is a device which converts a physical quality such as temperature, pressure, displacement, force, etc., into equivalent electrical signal either voltage or current.
2. **Active Transducers** : Active transducers are self generating type of transducers. These transducers develop an electrical parameter (i.e. voltage/current) which is proportional to the quantity under measurement. These transducers do not require any external source or power for their operation.
3. **Passive Transducers** : Passive transducers do not generate any electrical signal by themselves. To obtain an electrical signal from such transducers, an external source of power is essential. Passive transducers depend upon the change in an electrical parameter (R, L or C). They are also known as **externally power driven transducers**.
4. **Primary Transducer** : A transducer which converts physical quantity into mechanical signal is called **primary transducer**.
5. **Secondary Transducer** : A transducer which converts mechanical signal into an electrical signal is called **secondary transducer.**
6. **Electrical Transducer** : A transducer which gives output in electrical form it is known as **electrical transducer**.
7. **Sensor** : Sensor is a device that produces a measurable response to a change in a physical condition, such as temperature or thermal conductivity, or to a change in a chemical concentration.
8. **RTD** : Electrical resistance of any metallic conductor varies according to temperature changes. The primary electrical transducer which measures the temperature using this phenomenon is called Resistance Temperature Detector (RTD) or Resistance Thermometer.
9. **Thermistor** : Thermistors are semiconductor device which behave as thermal resistors having negative temperature coefficient [NTC]; i.e. their resistance decreases as temperature increases.
10. **LVDT** : LVDT (Linear Variable Differential Transducer) is a variable inductance displacement transducer in which the inductance is varied according to the displacement.
11. **Photoelectric Effect** : When the ray of light is incident on metal surface, the quantum energy of electron is converted to kinetic energy causing the electrons to move and thus resulting into flow of current in the metal. This phenomenon is known as **photoelectric effect**.

Resistive Transducers

- In general, the resistance of a metal conductor is given by,

$$R = \frac{\rho L}{A}$$

where ρ = Resistivity of conductor (Ω m)

L = Length of conductor (m)

A = Area of cross-section of conductor (m^2)

- The electrical resistive transducers are designed on the basis of the methods of variation of any one of the quantities in above equation; such as change in length, change in area of cross-section and change in resistivity.
- The resistance change due to the change in the length of the conductor is used in translational or rotational potentiometers to measure linear or rotational displacement. The change in resistance of conductor or semiconductor due to the strain applied is the working principle of the strain gauge which is used to measure various physical quantities such as pressure, displacement and force. The change in resistivity of conductor due to the temperature variations causes change in resistance. This principle is used to measure temperature.

Resistive Thermometers or Resistance Temperature Detector (RTD)

- The resistance of a conductor changes when its temperature changes. This property is used for the measurement of temperature. The resistance thermometer determines the change in the electrical resistance of the conductor to determine the temperature.

- The relationship between temperature and resistance of conductor is given by equation :

$$R_t = R_{ref} [1 + \alpha \Delta t]$$

Where

R_t : Resistance of the conductor at temperature t °C,

R_{ref} : Resistance of the conductor at the reference temperature, usually 0 °C,

α : Temperature coefficient of the resistance,

Δt : Difference between the temperature to be measured and reference temperature.

- Almost all metallic conductors have a **positive temperature coefficient** so that their resistance increases with an increase in temperature.
- A high value of α is desirable in a temperature sensing element so that a substantial change in resistance occurs for a relatively small change in temperature.
- This change in resistance [ΔR] can be measured with a Wheatstone bridge, the output of which can be directly calibrated to indicate the temperature which caused the change is resistance.

- At 0 °C, the resistance of RTD is usually 100 Ω. By choosing R_3 = 100 Ω and $R_1 = R_2$, the bridge is balanced at 0 °C. Therefore, at 0 °C voltage across B and D is zero and hence the output voltage is zero.
- Any change in the RTD resistance due to change in temperature unbalances the bridge circuit resulting voltage across B and D terminal. This voltage is proportional to the change in the resistance and hence to the change in the temperature.

change in the electrical resistance of the conductor to determine the temperature.

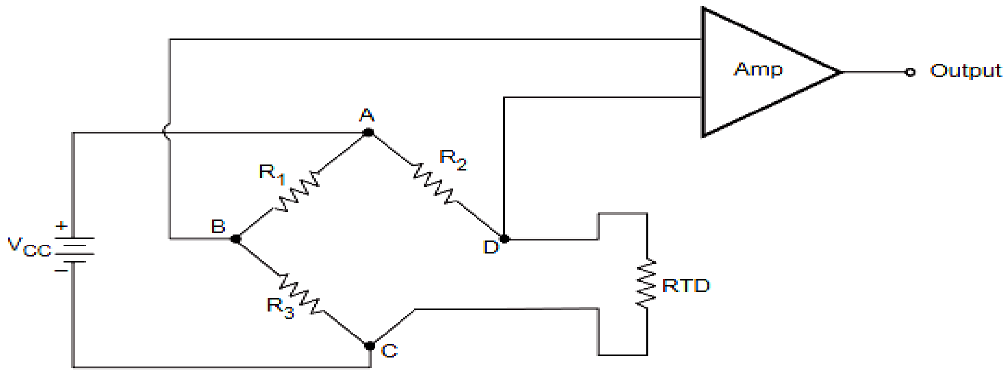


Fig. RTD resistance measurement

Thermistor

- **Thermistor** are the thermally sensitive resistor. They are having negative temperature coefficient (NTC).i.e. resistance decreases as temperature increases.

Operating Principle:

The resistance of Thermistor can be expressed as,

$$\mathbf{R_T = R_1 \exp[\beta(1/T_2 - 1/T_1)]}$$

Where R_T :Resistance at T^0 K

R_1 : Resistance at known temperature T_1 K

β:characteristic temperature.

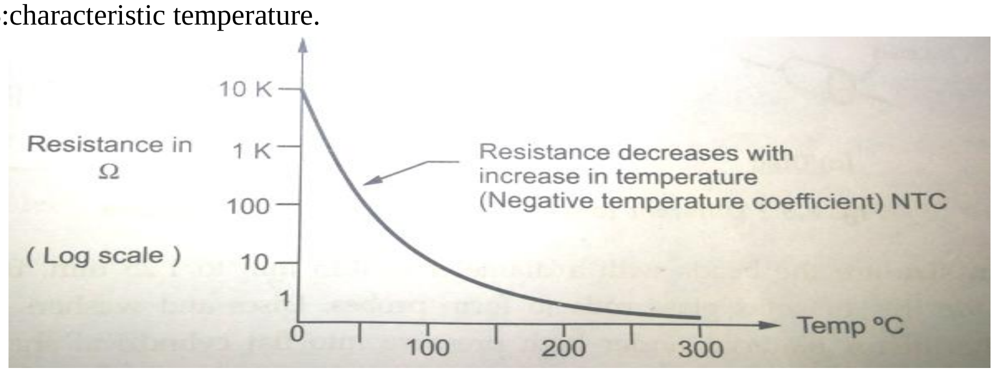


Fig: Resistance versus temperature characteristics of Thermistor.

- According to the characteristics the Thermistor provides a large change in the resistance for small change in temperature.
- Measurement of change of Thermistor due to temperature changes is measured using Wheatstone bridge.

Comparison

Parameter	Resistance Thermometer	Thermistor
Principle of operation	Resistance increases with increase in temperature	Resistance decreases with increase in temperature.
Temperature coefficient	Positive	Negative
Characteristic	Linear	Nonlinear
Sensitivity	Medium	High
Speed of Response	High	High over narrow temperature range
Operating temperature range	− 200 °C to + 650 °C	− 100 °C to + 200 °C
Type of transducer	Passive	Passive
Accuracy	High	Moderate
Size	Large	Small
Cost	High	Low
Material used	Nickel, Copper, Platinum etc.	Manganese, Nickel, Cobalt, Copper, iron and uranium
Compensation	Not required	Not required
Applications	Suitable for applications where speed of response and accuracy are more important.	Suitable for applications where required temperature range is small and sensitivity requirement is high.

Linear Variable Differential Transducer (LVDT) ****

- **LVDT** is a variable inductance displacement transducer in which the inductance is varied according to the displacement.

Operation of LVDT

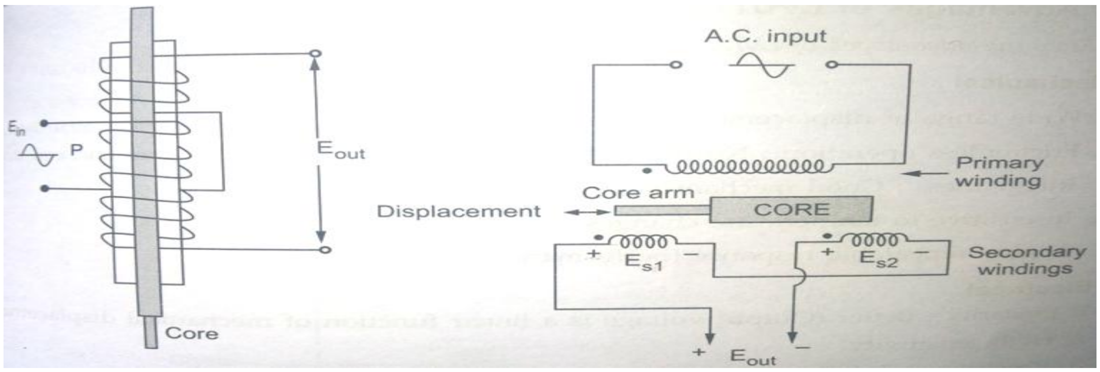


Fig. LVDT

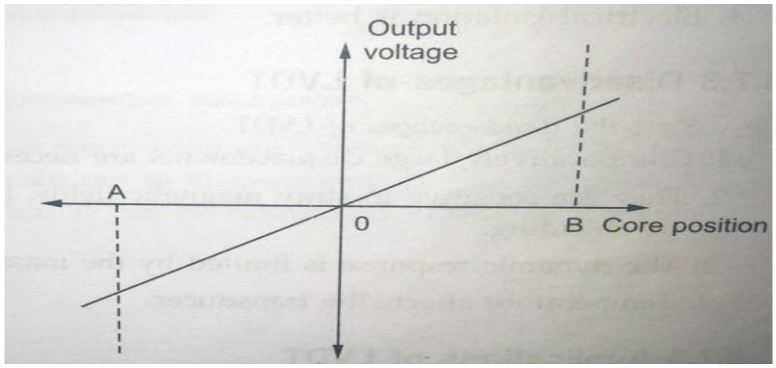


Fig. Output Voltage of LVDT at different core position

- In LVDT the inductance is varied by varying the mutual inductance between the two coils of linear variable differential transformer.
- The linear differential transformer consists of a single primary winding P_1 and two secondary windings S_1 and S_2 wound on a hollow cylindrical former. the secondaries have an equal number of turns but they are connected in series opposition so that the emf induced in the coils oppose each other and the output voltage is given by $E_{out}=E_{s1}-E_{s2}$.
- A movable soft iron core slides inside the hollow former. the position of the movable core determines the flux linkage between the a.c. primary winding and each of the two secondary windings. The core is made up of nickel-iron alloy is slotted longitudinally to reduce eddy current losses.
- When a.c. source is applied to primary and with the core in the centre or reference position, the induced emf in the secondaries are equal. since they oppose each other the output voltage will be zero volt.
- When the core is moved to the right ,more flux links the right hand coil than the left hand coil.i.e.$E_{S1}<E_{S2}$ .therefore E_{out} is negative.
- When the core is moved to the left ,more flux links the left hand coil than the right hand coil.i.e.$E_{S1}>E_{S2}$ .therefore E_{out} is positive.
- The amount of output voltage of an LVDT is a linear function of the core displacement within a limited range of motion.

Application:

1. The LVDT can be used in all applications where displacement ranging from fractions of a few mm to a few cm have to be measured.
2. Acting as a secondary transducer, LVDT can be used as a device to measure force, weight, and pressure etc. The force or pressure to be measured is first converted into a displacement using primary transducers. Then this displacement is applied to an LVDT, that acts as a secondary transducer, and converts the displacement into proportional output voltage. In these applications the high sensitivity of LVDT is a major attraction.

Advantages:

Electrical

1. Linearity : Better (Output voltage is a linear function of mechanical displacement).
2. High sensitivity.
3. Resolution : Infinite.
4. Electrical isolation is better.

Disadvantages:

1. Comparatively large displacements are necessary for appreciable differential output.
2. They are sensitive to stray magnetic fields. However, this interference can be reduced by shielding.
3. The dynamic response is limited by the mass of the core.
4. Temperature affects the transducer.

Active Electrical Transducers

Piezoelectric Transducers

The construction of the piezoelectric transducer is as shown in the Fig.

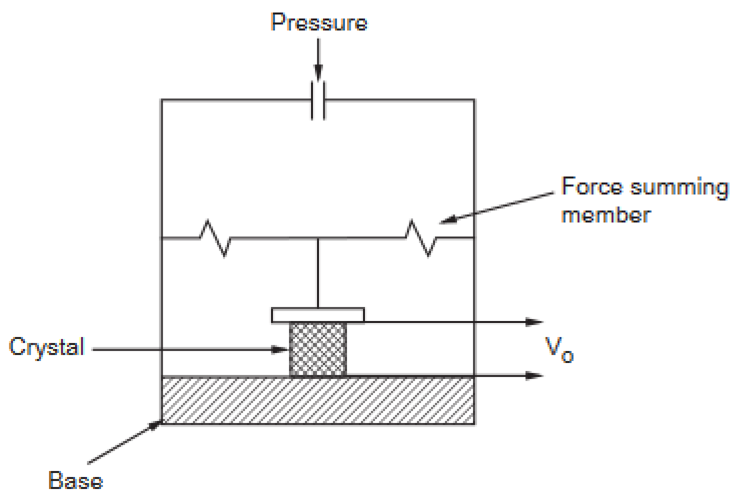


Fig. Piezoelectric transducer

A crystal is placed between solid base and force summing member. Metal electrodes plated on to faces of piezoelectric crystal are taken out to measure output. The electrodes become plates of the parallel plate capacitor. Thus it can be considered as charge generator. The output voltage is given by

$$V_o = \frac{Q}{C}$$

Photoelectric Transducers

- The principle of photoelectric transducers is the physical radiation on matter.
- When the ray of light is incident on metal surface, the quantum energy of electron is converted to kinetic energy causing the electrons to move and thus resulting into flow of current in the metal. This phenomenon is known as **photoelectric effect**.

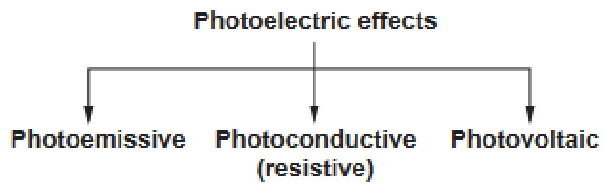


Fig. 8.5

- **Photo-emissive Transducer** consist of a metallic cathode and an anode in an evacuated tube. The electrons emitted by the cathode are attracted by the anode, causing the current to flow which is proportional to the amount of light incident on the metal surface. The optical radiation affects either the current developed voltage or resistance.
- **Photovoltaic cells** are self generating and are favoured for use in exposure meters.